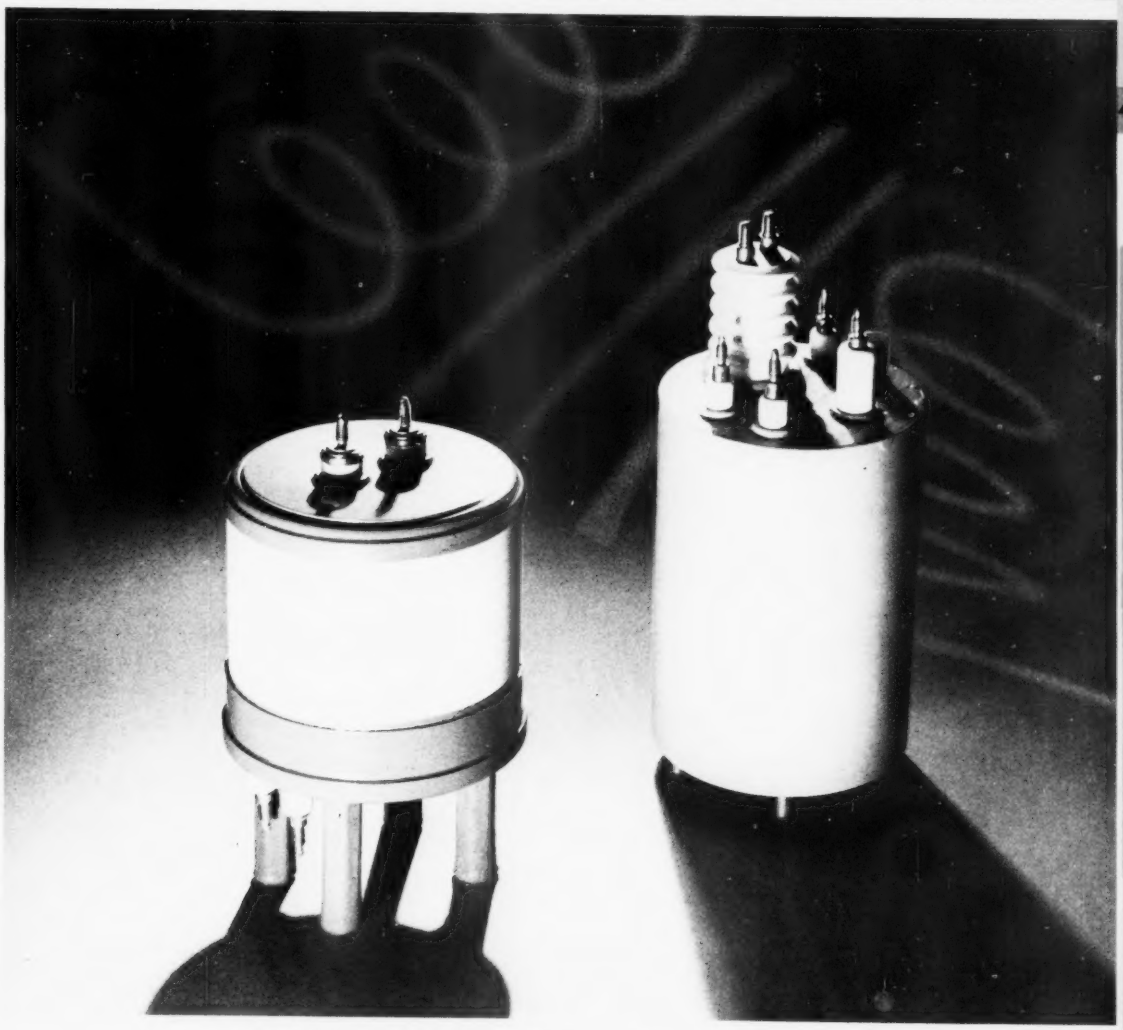
RAYTHEON

ELECTRONIC PROGRESS

NOVEMBER
DECEMBER 1957



Raytheon's New Power Transformers

In this issue: **FLUOROCHEMICAL COOLANT-DIELECTRICS**

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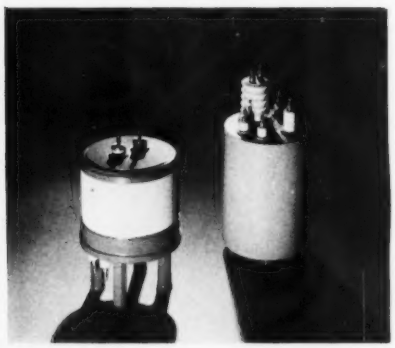

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Committees

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Ferrite	*L. Davis, Jr.*	Welding	*R. Eckler*
Magnetic Amplifiers	*D. McMurtrie*		

Inventions

Congratulations to the following persons for their valuable contributions to Raytheon's portfolio of inventions:

Name	*Field of Invention*
Joseph Apelbaum	Impregnated Emitter
Kenneth Dudley	
Saul Bergmann	Broadband Matching Transformer
H. Scharfman	
John Buckbee	Storage-Tube PPI Compensation Circuit
A. S. Luftman	
Frank Taylor	
John Buckbee	Spiral Scan
Frank Taylor	
Peter Kaufmann	HF Transistor Trim Capacitor
Saul Lederhandler	Infrared Transmittance in Silicon
R. Maartmann-Moe	RF Noise Suppressor
R. Pucel	Semiconductor Device
H. Statz	
Burton Rawding	Resonance Indicator
Marshall Sirvetz	Low Frequency Ferrite Composition
Jean N. Tariot	Comparator Circuit

Calendar

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Fluorochemical Coolant-Dielectrics	*J. F. Ahearn, L. F. Kilham and R. R. Ursch*	1
The Electrocardiograph	*J. Welts*	4
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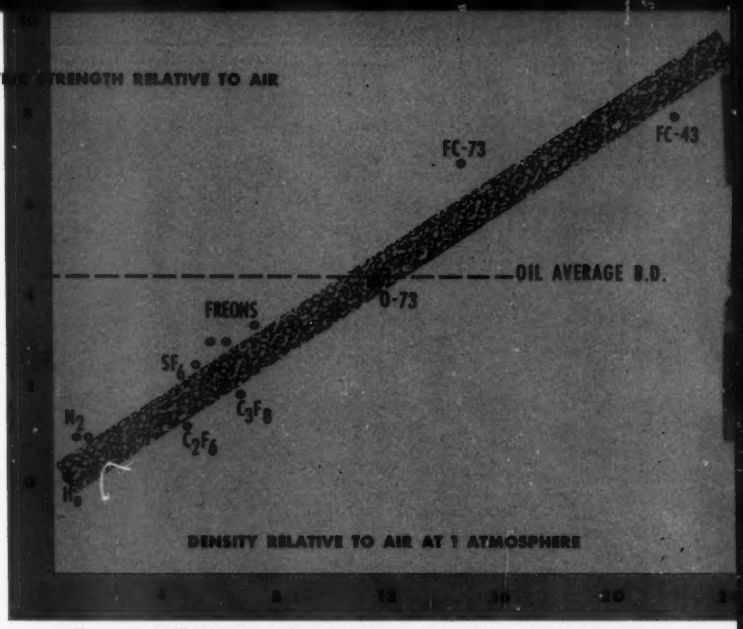

Figure 1. DIELECTRIC STRENGTH OF GASES AT 1 ATMOSPHERE

Fluorochemical COOLANT-DIELECTRICS

J. F. Ahearn
L. F. Kilham
R. R. Ursch
Commercial Equipment Division

Reduction in size and weight, and improved reliability are considerations of prime importance in the design of electronic equipment, particularly for airborne use. Reduction in size is almost invariably associated with an increase in thermal density, expressed as watts dissipated per cubic foot. Increased thermal density tends to aggravate the reliability problem because of the higher operating temperatures of materials and components. Progress in the miniaturization of components and equipment, therefore, is dependent to a large degree on two factors: improved heat transfer techniques, and thermally stable materials.

Fluorochemical products in the form of teflon, or polytetrafluorethylene, are familiar to every electronic engineer who has designed high temperature equipment. Teflon is a compound made up of carbon and fluorine atoms aggregated in very large molecules. Its outstanding thermal stability is due to the fact that fluorine is the most reactive element in nature, and once it combines with another element, such as carbon, the chemical bond can be broken only by the expenditure of a large amount of energy. Recently a new class of fluorochemical liquids and gases have become available which, in a sense, may be regarded as liquid or gaseous teflon. These substances exhibit many remarkable properties which render them of particular utility both as heat transfer media and as thermally stable dielectric fluids.

The fluorochemical liquids are clear, water-white, practically odorless, and as free-flowing as water. Their thermal stability is attested by the fact that they may be passed through tubes heated to 500° C without significant decomposition. They have been found to be non-corrosive to metals at temperatures up to 200° C in the absence of moisture. They have no solvent effect on plastics and varnishes, and are nontoxic.

Of particular interest with relation to the use of these materials in high voltage apparatus are their excellent dielectric properties. Breakdown strength, power factor, and resistivity of purified samples in the liquid state are equal to or better than those of the best dielectric oils. Breakdown strength of the vapors increases with increasing molecular weight,

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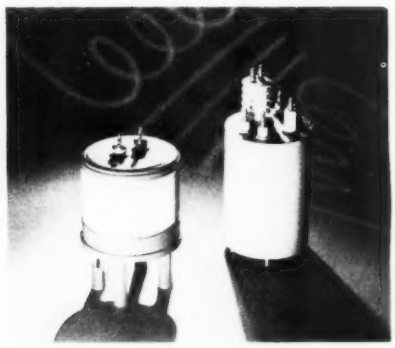

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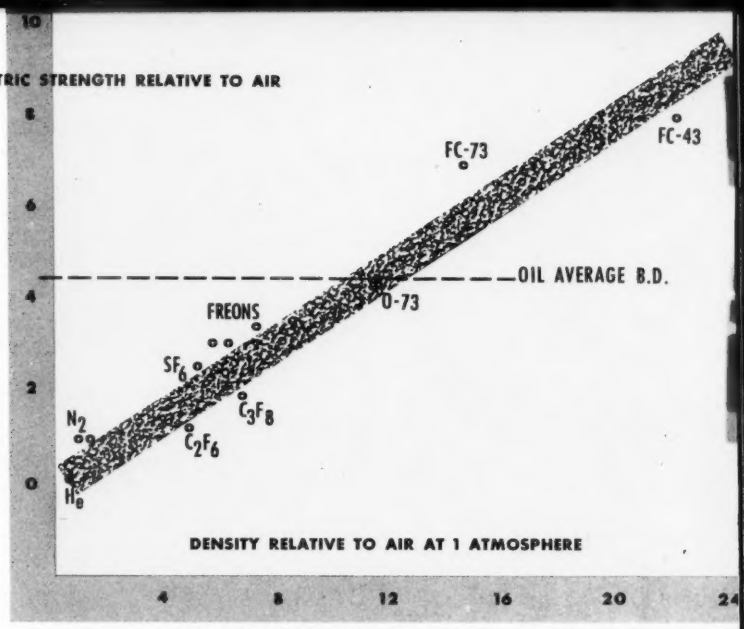

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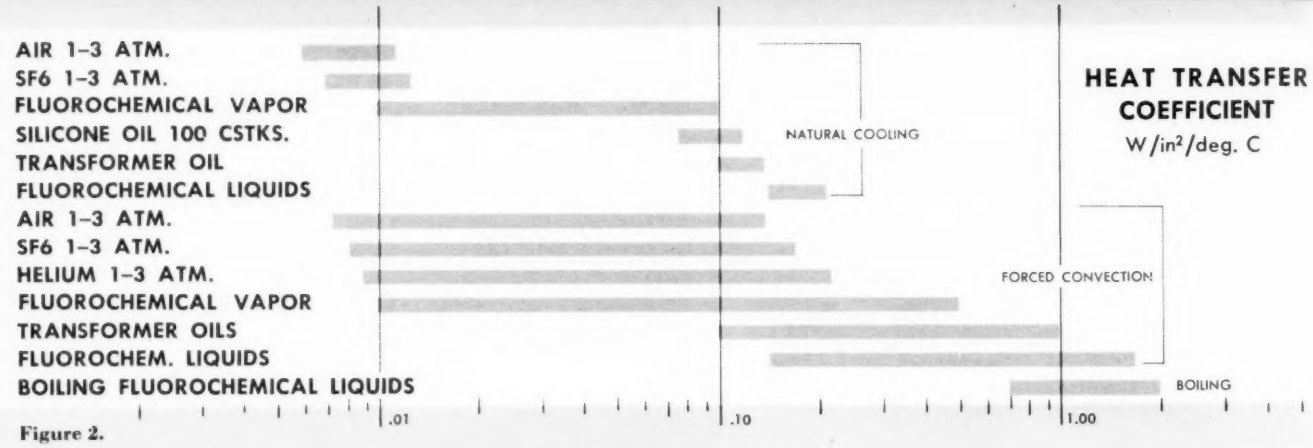

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boiling point, and density. A curve of dielectric strength relative to air versus density of the vapor at atmospheric pressure for several gases and vapors is given in Figure 1. It is apparent from the curve that the vapors of fluorochemicals 0–73, FC 75, and FC 43 are equal to or better than oil in dielectric strength. Thus, in many applications it is possible to replace oil by gas or vapor, with significant saving in weight.

The physical properties of the fluorochemical liquids and gases are such as to make them especially effective as heat transfer agents. Heat transfer in electronic equipment can be accomplished in a number of ways. Conventional methods include metallic conduction, the use of air by natural or forced convection, and oil cooling.

The disadvantages of air as a coolant fluid are chiefly two: low dielectric strength and relatively ineffective heat transfer. The use of oil involves a weight penalty. Several new heat exchange techniques making use of the special properties of the fluorochemical liquids and gases have been devised. These may be classified as follows, in order of increasing effectiveness:

1. Natural convection in fluorochemical vapor.
2. Natural convection in fluorochemical liquid.
3. Forced convection in fluorochemical vapor.
4. Forced convection in fluorochemical liquid.
5. Boiling of fluorochemical liquid followed by condensation of the vapor.

A comparison of the relative effectiveness of these and conventional techniques is given in Figure 2. A study of this chart reveals a number of interesting facts. Transformer oils as cooling media are roughly ten times as effective as air; fluorochemical vapor of high density is more effective than helium, which, next to hydrogen, has always been considered the ultimate among cooling gases. With forced convection, fluorochemical vapor is superior to naturally circulating oil, a remarkable fact when one considers the vast difference in weight between vapor and oil. A boiling fluorochemical liquid provides the best cooling effect of all presently known methods for cooling electronic equipment, and although a penalty is incurred due to the weight of liquid, this method is particularly suited to applications of extreme heat concentration where high voltages of 10 KV and upwards are involved.

Heat transfer in gases and liquids is determined by a number of properties, such as thermal conductivity, density, coefficient of expansion, specific heat, and viscosity. The fluorochemical gases and liquids, while not outstanding as far as thermal conductivity and specific heat are concerned, have exceptionally high density and low viscosity. The vapor of FC 43, for example, is 22 times as heavy as air. The liquids have a coefficient of expansion from 2 to 3 times as great as that of conventional oils. These factors add up to unusual heat transfer qualities, both in natural and forced convection.

The idea of cooling a transformer by placing it in a boiling liquid may seem a bit radical to the uninitiated. Nevertheless, model transformers using this technique have been found to run at unusually low temperatures. The boiling liquid acts as a thermostat, since its boiling point under a given set of operating conditions is fixed. A transformer cooled in this manner is illustrated in Figure 3. The vapor, on coming in contact with the cooler surface of the container in which the transformer is housed, condenses back to its original liquid state, thus giving up its heat to the surrounding atmosphere. By providing a moderate current of cooling air flowing past the case, condensation is accelerated and rate of heat transfer greatly increased. A similar technique is applicable to equip-

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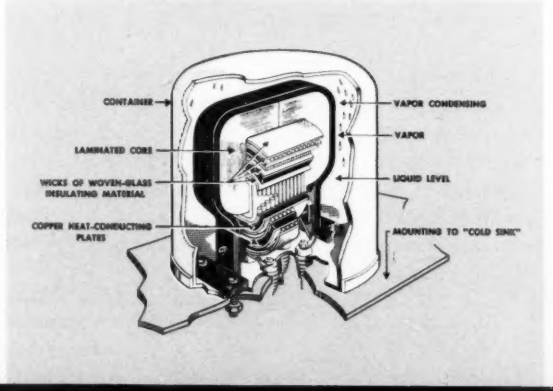
CUTAWAY VIEW OF RAYTHEON FLUOROCHEMICAL TRANSFORMER



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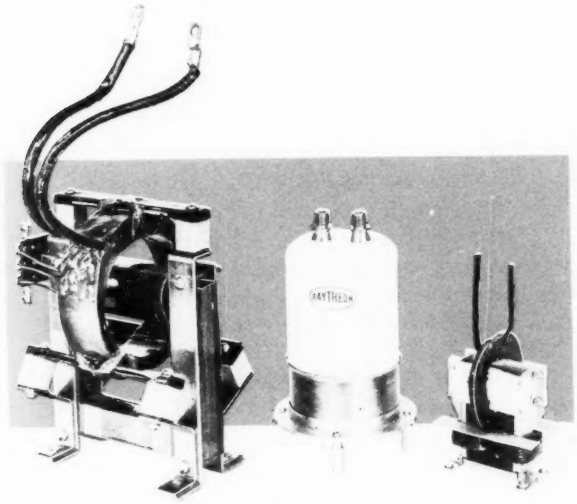
The variety of fluorochemical gases and liquids available makes it possible to specially design, or "tailor" a cooling system for any particular set of requirements. In the design of a system, special attention must be paid to such requirements as maximum size and weight, maximum and minimum ambient temperatures, altitude, type of external



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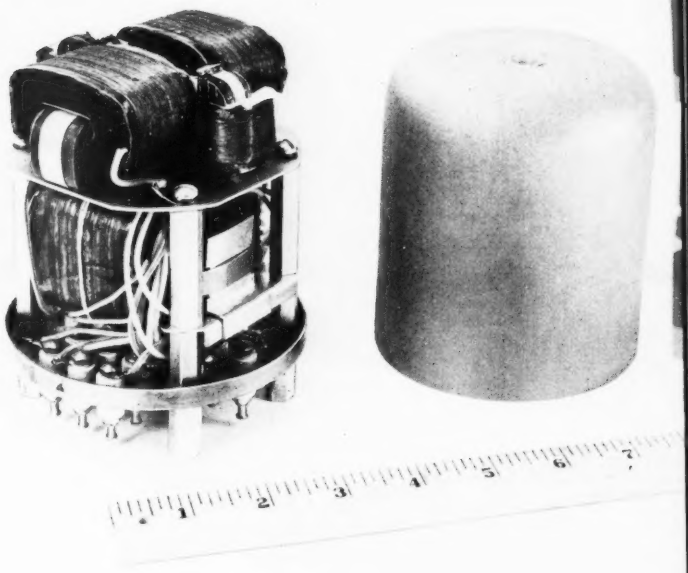
Raytheon Transformer Department's Heat Transfer Laboratory has during the past three years been engaged in the application of the new techniques in instances where environmental conditions are too severe for conventional methods or where it is desired to reduce size and weight to a minimum.

A number of transformer designs have been evolved in which gases and vapors have been used in place



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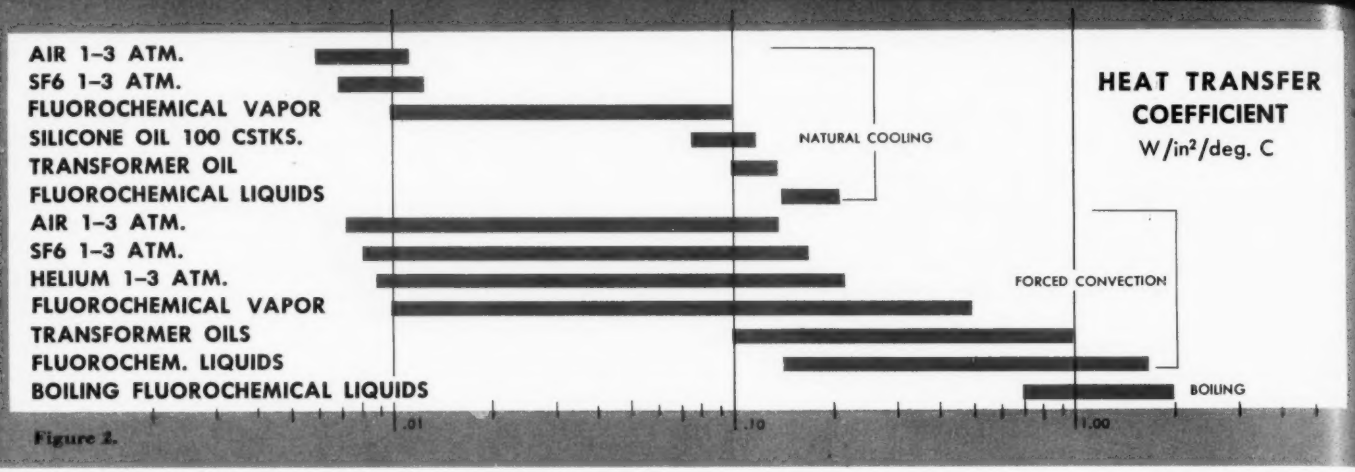
Recent work of the laboratory shows a definite trend away from the concept of individually packaged components, toward a single package in which high-voltage high power units are assembled in a hermetically sealed case protected from the effects of varying temperature and altitude. The package system not only makes possible the use of a carefully designed, optimized cooling and insulating system, but reduces by a large factor the over-all volume of the equipment because of the elimination of numerous high-voltage bushings and individual cases. In actual experience, savings of 50% are not at all uncommon. The future will undoubtedly see an ever-increasing trend to this type of packaging.



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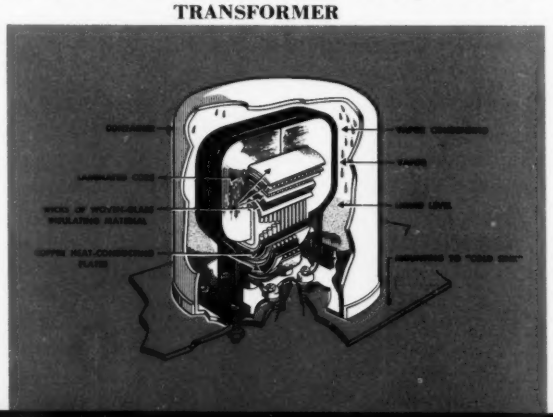

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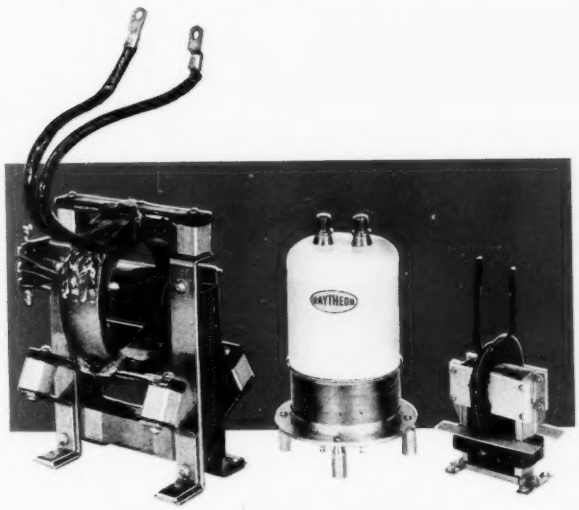

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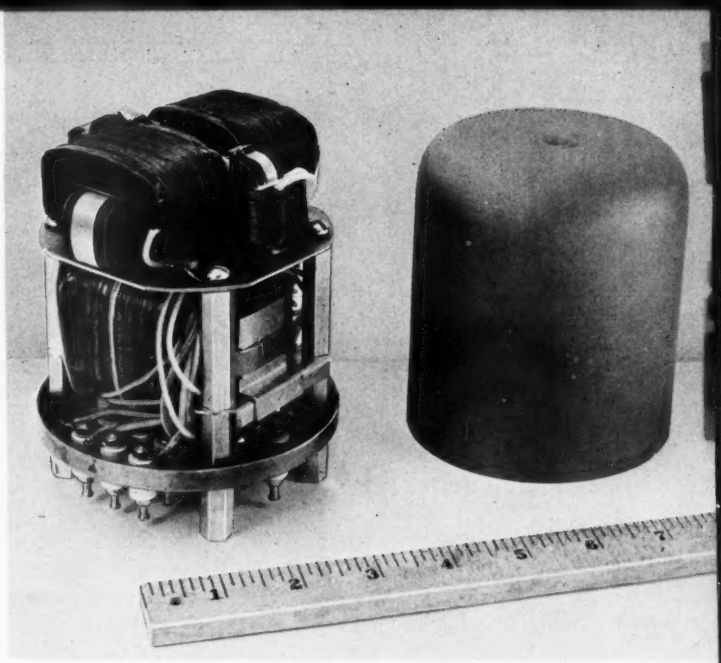

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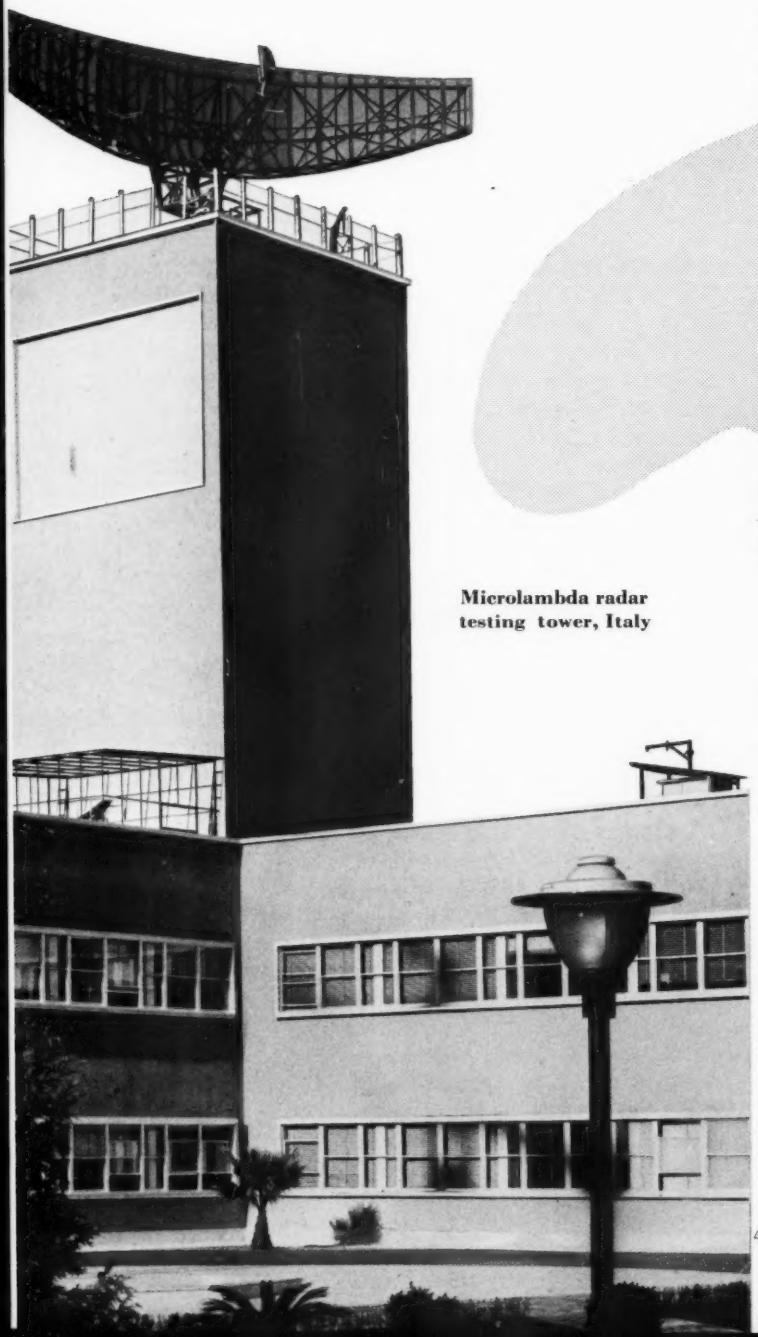


Microlambda radar testing tower, Italy

The significance of Raytheon's International Operations manifests itself almost daily in the conference rooms at Waltham. Scientists, engineers, industrialists and government officials come from every land, seeking information about one or more of Raytheon's electronic developments.

The commanding officer from the Indonesian Police Patrol comes to learn how radar can be applied to police work against smugglers. The owner of a large fishing fleet in Latin America wants to study the application of sonics to fish finding. The management of a broadcasting chain in Australasia desires to investigate the new microwave television relays. A European scientist seeks data on special subminiature tubes and semiconductors for guided missile application. Also, tons of mail come by ship and air on similar quests.

This world wide interest in Raytheon's activities is, of course, encouraged. Raytheon's overseas marketing organization greatly facilitates the dissemination of news and information. Consisting of two divisions, Export Sales and Licensing, this organization extends to 65 countries in six continents.

The Export Sales Division is represented by 83 carefully selected distributing firms, fully qualified to promote the sale of Raytheon products and to maintain service in their respective countries. Supplementing these insofar as radar and marine products are concerned, servicing facilities are maintained at 167 strategically located ports.

The establishment and maintenance of such worldwide service is a tremendous undertaking, presenting many unique problems. Marine equipment, particularly radar, is complicated and delicate, and servicing it demands a thorough knowledge of the features and characteristics of a variety of models. A multiplicity of parts is required for a full complement of spares, and these must be available when needed. Much of the world's sea traffic consists of vessels, such as tankers, which often load and unload at remote ports with limited turn-around periods, frequently less than 24 hours. This brief availability adds to the servicing problems.

The environments under which the equipment must operate subject it to the most gruelling tests of endurance. In the Arabian-Persian Gulf areas radar must be used for navigation in violent sand storms blown out to sea. The continuous heat and humidity of the South China Seas and other tropical waters approach the high limits of heat and humidity of a test chamber. In the Baltic Sea an icebreaker reported that its radar waveguide acted like a chimney. Moist warm air from

Atlas-Werke plant, Germany

the ship's interior was conducted up through the waveguide where it condensed and froze into solid ice.

To cope with servicing problems often encountered for the first time is the task of Raytheon's service engineers. From New York to Cape Town, from Rio de Janeiro to Reykjavik, from Tokyo to Tandjung Priok, from the most famous to the most obscure of the world's ports, Raytheon's service organization endeavors to provide master mariners everywhere on-the-spot service when they need it most. The fact that a burned out transformer can be rewound, repaired and restored to service at some obscure port in the tropics is indicative of the calibre of the service offered to those who sail to distant lands.

In the Licensing Division activities extend to manufacturers overseas who have been granted the right to manufacture selected equipment on a royalty basis under Raytheon's patents, know-how and/or trademarks. This work requires the most exacting liaison engineering. Manufacturing procedures and techniques, testing methods, technical instructions and personnel training have to be supplied.

Though these licensees are leading manufacturers in their respective countries, the equipment to be made under license may be new both to their management and technical staffs. Often an entirely new organization has to be established. The methods of procedures will vary in details from country to country and according to type of equipment, but the basic problems form a definite pattern. This can best be illustrated by a specific case history.

One of the first radar equipments to be made in Europe under Off Shore Procurement awarded by the United States Navy Department, Bureau of Ships, was the AN/TPS-1D, a transportable air search radar equipment. Raytheon, who produced the equipment for the Armed Forces was assigned the responsibility of setting up facilities for its production in Europe.

Microlambda, organized as one of the Finmeccanica group in Italy, was selected to produce the equipment. Buildings had to be built, personnel trained and liaison engineers supplied to supervise the operations.

While the AN/TPS-1D is similar in operation to most search radars that consist of a modulator, transmitter-receiver, rotating antenna and indicator providing azimuth and range information with PPI and A-scope presentations, it departs from the typical in featuring a Moving Target Indication (MTI) system. When switched from normal radar operation to MTI operation, the clutter of fixed objects is removed from the indicator, thus aiding in the detection of moving objects.

One of the components used in the MTI circuitry is the Mercury Delay Line. The long delay (2500 usec) and wide band-width (3 mc) of the delay line are obtained by converting the electric pulse signal into a mechanical vibration equivalent and transmitting it through a liquid medium. The delay line is but one component in a radar system. It has been described to illuminate the problems encountered in setting up manufacturing under foreign license. Since this delay line had to be made in Italy by one of Microlambda's suppliers, Italian engineers had to be thoroughly trained by Raytheon engineers in the Delay Line Laboratory in Waltham.

After training, the Italian engineers returned to their country to set up facilities for production. Two Raytheon Liaison Engineers were also sent to Italy to assist with production and testing problems. Two defective delay lines or "rejects" were used to test the new production facilities and engineering capabilities. The newly trained Italian engineers completely disassembled, restored and reassembled the rejects, after which the delay line was tested and found to be well within required specifications. All of this was done under the guidance of Raytheon Liaison Engineers. After this demonstration of engineering and testing capability, the newly developed mercury delay lines were put into production.

It must be remembered that all other components and assemblies comprising the AN/TPS-1D had to be developed and produced along a similar *modus operandi*. It is significant to note that the first AN/TPS-1D

was delivered by Microlambda nine months after they were given the contract and that the equipment conformed to the most rigid United States Armed Forces specifications for the Off Shore Procurement Program.

Encouraged by the Evans Signal Laboratory of the U. S. Army Signal Corps, as well as representatives of the U. S. Marine Corps in the Bureau of Ships, and with assistance from Raytheon engineers, Microlambda contributed to the development of the Cosecant-squared antenna for the AN/TPS-1D radar system. In addition, an improved Signal Mixer, Gated MTI operation and a Fused Silica Delay Line, an improvement over the Mercury Delay Line, resulted in improved reliability, as well as in increased range and vertical coverage.

Today Microlambda is one of the leading electronic manufacturers in Europe, highly rated for the quality

Manufacturing plant of Oki Electric Industry Co., Japan.

of its production. Its plant has a working floor space of 140,000 square feet and averages a production volume equivalent to $6,000,000 per year, 70 percent of which is Raytheon licensed products. It employs 460 engineers, technicians and skilled craftsmen and maintains a highly competent research staff.

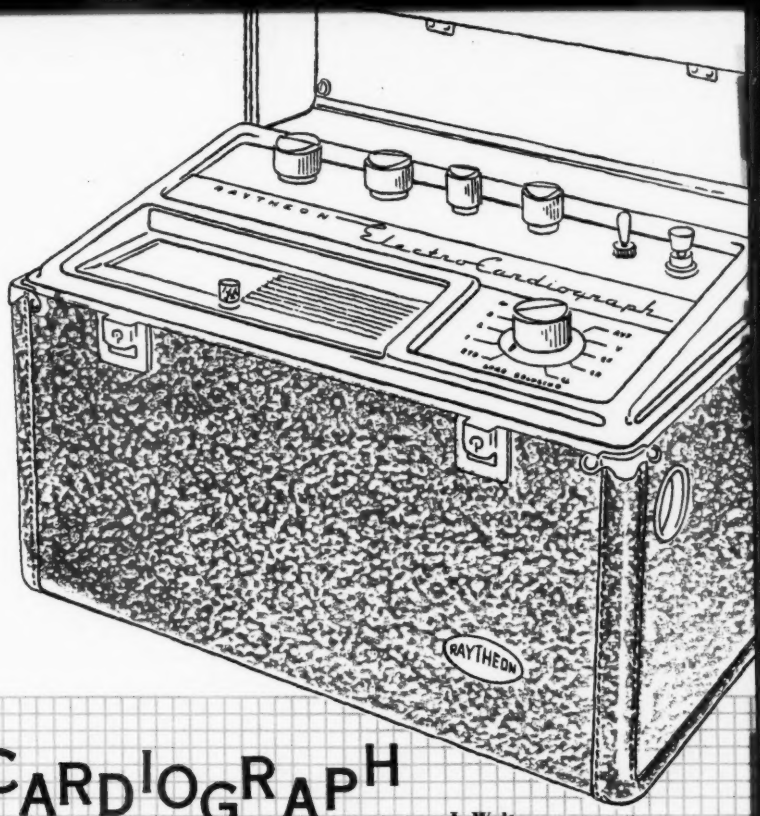
Among the most recent developments are a new shipborne air search radar, a shipborne automatic tracking fire control radar, the L-band 45-foot cosecant squared antenna, a six-channel telephone microwave relay and a 50 KW navigation radar. Perhaps the most significant achievement in the Off Shore Procurement Program is the fact that 90 percent of all mechanical and electrical components are made interchangeable with U.S. built components, thus establishing a reliable source of supply for many JAN type components which heretofore were non-existent.

Many Raytheon licensees have been leading manufacturers for a half century or more, and have been pioneers in their respective fields. Atlas-Werke of Germany, for example, was established more than fifty years ago and pioneered in the development of echo depth sounding and echo ranging in Europe. It is Raytheon's oldest licensee, having originally (1912) been affiliated with Submarine Signal. It is one of the largest marine suppliers in Europe and operates a shipyard in which vessels up to 7,000 dead weight tons are built. It employs more than 3,000 people, among which are 180 physicists, engineers and technical specialists, many of whom hold Ph.D. degrees. It has one of the best equipped research laboratories and is constantly engaged in scientific research. It is one of the most important developers and manufacturers of advanced electro-medical equipment including multi-channel electrocardiographs, oxymeters and encephalographs. During the past three years it has manufactured more than 200 Raytheon Model 1500 Radar systems. Atlas' volume of production exceeds $15,000,000 annually.

On the opposite side of the globe in Japan another licensee has been established since 1881. The Oki Electric Industry Company began the manufacture of telephone equipment only five years after its invention by Alexander Graham Bell in 1876. Electrical apparatus and later electronic equipment was added to the line and in 1954 it was granted a license to manufacture Raytheon's radar and other marine electronic equipment. Among its 3500 employees more than 2000 are physicists, engineers and technicians. With a floor space of more than a million square feet, its production approximates $5,000,000 annually. Oki-built radar is distributed and serviced by Daiichi Bussan Kaisha, Ltd. in Japan.

The original inventions of Raytheon licensees and their contributions towards improvement of Raytheon equipment, as well as their methods and processes of manufacture, are of utmost value. Among such contributions can be included Atlas-Werke's "Fishfinder" which has now been added to the Raytheon line, an improved 40-foot L-band antenna and such new radar developments as Microlambda's MLN-1B, Oki's Model 12 and Atlas Werke's repackaged Model 1500, all of which are available to Raytheon.

This two-way exchange of technical ingenuity and engineering development continues to grow in significance as licensees acquire more engineering and manufacturing experience. When one considers that these licensees have to take working drawings printed in this country, do their own translation and conversion of measurements to the metric system and then make complicated electronic equipment, often with only limited instructions, to meet the most rigid specifications, one realizes more fully the magnitude of their task. That in addition to this achievement they can actually contribute to the improvement of such equipment is one of the marvels of joint effort and international cooperation.



the ELECTROCARDIOGRAPH

J. Welts
Commercial Equipment Division

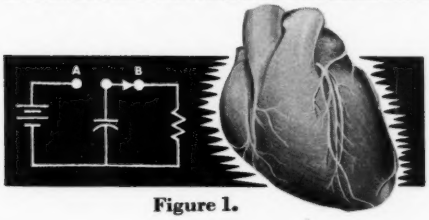


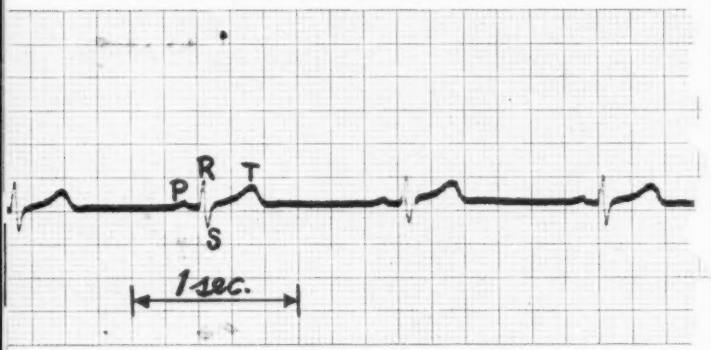
Figure 1.

It has been known for over seventy-five years that a measurable amount of electric current in the body is associated with the action of the heart. Measurements of these currents were extremely difficult until Einthoven developed a galvanometer system that was sensitive to 1 mV pulses. This galvanometer system consisted of a quartz glass fiber (8 microns in diameter) suspended in the field of a strong magnet. The fiber — or string — was plated with a coating of platinum or silver. When a current was passed along the fiber, the fiber moved according to the well-known right hand motor rule. The deflection of the string was amplified optically and its shadow was recorded on photographic film. This system was disclosed by Einthoven in 1903 and was used almost exclusively until the middle 1930's.

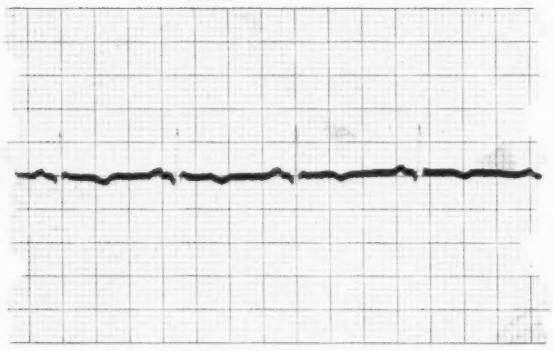
With advances in vacuum tube technology and circuit design, a new type of electrocardiograph began to take form. The amplifying equipment was placed between the signal source (the patient) and the galvanometer. This allowed the use of much more serviceable equipment, even though it was still necessary to use photographic processes to record the traces. The most recent advance has been the introduction of direct writing equipment. The first attempts were with pen and ink tracings. These were successful to a moderate degree, but ink splatter, inadequate ink reservoirs and curvilinear records were decided disadvantages. The development of a special heat sensitive paper coupled with a hot wire stylus writing on a knife edge has brought the state of the art up to its present level where it is possible to examine an electrocardiographic record as it is being taken, and store this same record for an indefinite period of time.

A great deal of research has been done in order to analyze the mechanisms of the heart muscle which produce the electrical pulses recorded on the electrocardiograph. Two distinct processes take place; the first is strictly an electrical discharging action similar to the discharge of a condenser—this is the depolarization process and occurs very rapidly; the second is the repolarization process which is an electro-chemical reaction. The electro-chemical reaction is slower, but for the same membrane the energy handled in the two processes is the same. An electrical analogy of this process can be seen by connecting a battery, a condenser, and a resistor as shown in Figure 1. When the switch is at "A", the condenser charges because of the electro-chemical reaction going on in the battery. When the switch is at "B" the condenser simply discharges through the load resistor.

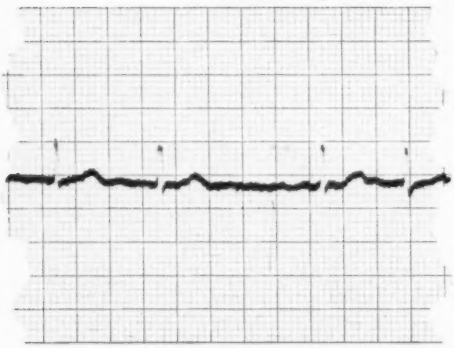
The actual heart action is not quite as simple as our electrical analogy in that the heart pulse is not a scalar quantity. The pulse is a true vector in that it has time sense, magnitude and direction. This comes about from the fact that the heart membrane is not the point source we considered it in our analogy. The stimulator that starts the heart action—the switch in the analogy—is located in the upper right hand corner of the heart. This triggers polarized cells in the heart in such a fashion that a periodic voltage varying in space and time is generated. This vector first points to the right shoulder and then rotates downward looking towards the toes, then around to the left shoulder and back to the right shoulder.



The electrocardiograph is significant because it can be used to identify heart irregularities indicative of pathological conditions which might otherwise go unnoticed. This tracing taken from a normal heart is labelled to show the key areas. Notice the rhythmic repetition of the basic pattern.



Here the T wave is inverted, indicating, in this particular case, coronary disease.



The irregular rhythm of this tracing, as well as the absence of P waves, indicate to a cardiac specialist the presence of auricular fibrillation.

Einthoven devised a systematic means of looking at this rotating vector using combinations of three electrode positions; the right arm, the left arm, and the left leg. Lead I measures the potential between the right and left arms. This lead illuminates a plane parallel to the top of the heart. Lead II connects the right arm and the left leg, and Lead III illuminates a plane parallel to the left side of the heart by being connected between the left leg and the left arm. By recording these three leads simultaneously, it is possible to exactly locate the position of the heart voltage vector both in space and in time. This defines *Einthoven's Law*, which states that the algebraic sum of any signal recorded on Lead I and on Lead III at any given instant is equal to the signal recorded on Lead II at the same instant. Generally, the signals from these three leads are recorded in sequence on a single channel instrument; here Einthoven's Law is a useful tool to ascertain if there is anything wrong with the instrument or the connections to the patient. Other lead combinations are included on all modern ECG instruments but they are only intended to give a closer look at the rotating heart vector.

In the design of an Electrocardiograph instrument, both physiological and electrical considerations must be taken into account. Basically, the instrument must contain:

1. A comfortable, yet efficient means of connection to the patient.
2. An input switch which will select the various lead combinations.
3. An amplifier capable of handling signal voltages as small as 100 uV.
4. A means of permanently recording the heart voltages.
5. A constant speed chart drive mechanism to supply a known time base.

Connection to the patient is accomplished by the use of four "limb" electrodes and one chest electrode (Fig. 2). A saline paste must be applied to the skin underneath the electrodes to reduce skin resistance to a minimum. The electrodes are strapped to the four extremities with rubber straps and the chest electrode is either held in place with the hand or with a suction cup type device. A well shielded five conductor cable connects the electrodes to the instrument.

The various leads are connected to the amplifier in proper sequence by a multi-wafer rotary switch commonly called the patient switch. In some equipments,

this switch is designed to automatically disable the amplifier during the transient condition when switching from lead to lead.

The amplifier is usually designed so that at maximum gain, a 1.3 mV peak signal will deflect the recording stylus a minimum of 2.0 cm. Voltage gains on the order of 50,000 are common.

There are two major sources of interference that are applied to the input of the amplifier in addition to the heart voltage. The first source comes directly from the patient and is present on the patient in the form of a dc potential which may be as high as 100 mV. This potential may appear between any of the extremities and is usually found in a patient who has suffered an injury of some sort. The "injury current" is blocked out of the amplifier by the use of large series condensers. The low frequency response for the system is usually designed to be 3 db down at 0.4 cycles. The second important interference is radiated from the ac power lines. The magnitude of this interference depends on the patient's proximity to the source of radiation. The power line interference is cancelled out by using a balanced amplifier with the center tap of the input system connected to the right leg. There are other extraneous electrical signals that come from the patient which can only be eliminated by making sure that the patient is relaxed.

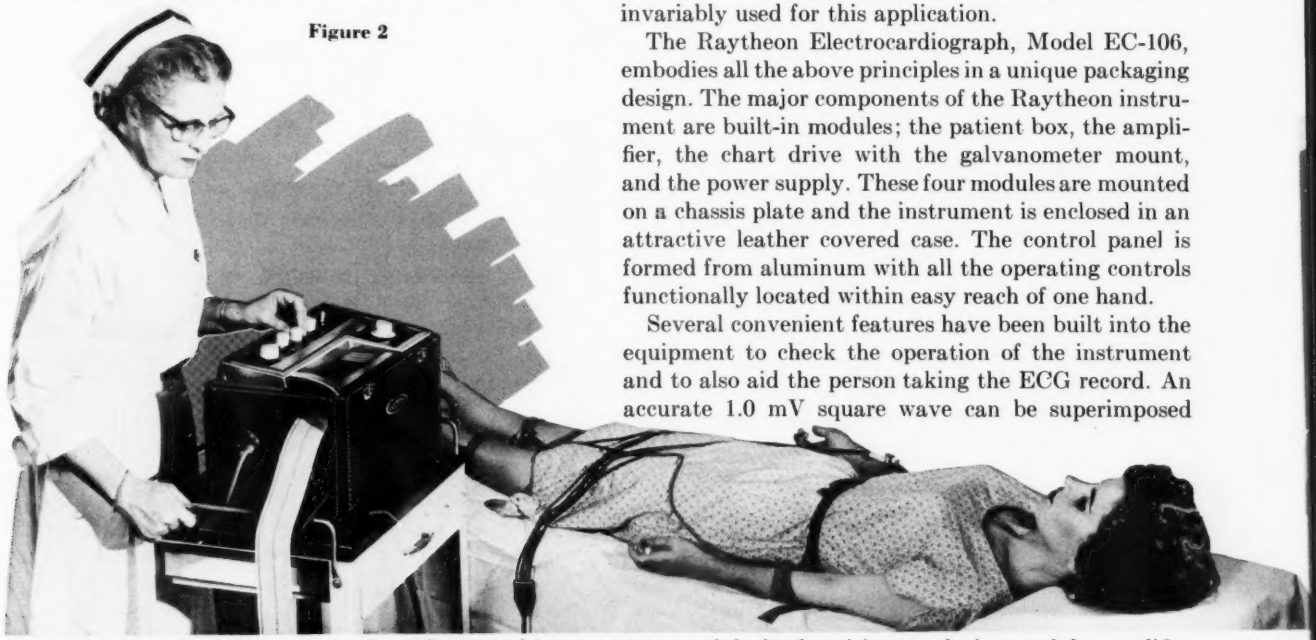


Figure 2

The recording mechanism consists of a galvanometer which drives a pen that has a resistance wire writing surface welded to the tip. The galvanometer requires power in the order of one watt to drive it to full excursion, and must be driven from a low impedance source to insure proper damping. The frequency response of the galvanometer limits the response of the instrument; therefore, the galvanometer must be designed to have as high a resonant frequency as is considered consistent with power requirements and ruggedness. Most galvanometers now used in cardiography have a resonant frequency in the range between 35 and 55 cycles. The frequency response of the system can be extended to a small degree by compensating the amplifier with some high frequency pre-emphasis, but overshoot—which cannot be tolerated—limits the amount of compensation possible. Most modern systems have an overall frequency response from a low of 0.4 cycles to an upper limit of 45 through 70 cycles depending on the particular manufacturer.

The chart drive mechanism must be capable of driving a roll of paper at least 150 ft. long at a constant speed of 2.5 cm/sec. The speed must be held constant within 2% for a wide range of line voltages. For this reason, gear-head synchronous motors are invariably used for this application.

The Raytheon Electrocardiograph, Model EC-106, embodies all the above principles in a unique packaging design. The major components of the Raytheon instrument are built-in modules; the patient box, the amplifier, the chart drive with the galvanometer mount, and the power supply. These four modules are mounted on a chassis plate and the instrument is enclosed in an attractive leather covered case. The control panel is formed from aluminum with all the operating controls functionally located within easy reach of one hand.

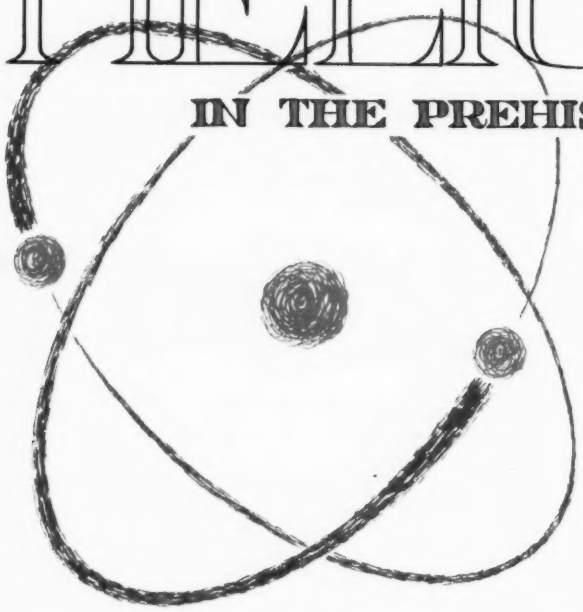
Several convenient features have been built into the equipment to check the operation of the instrument and to also aid the person taking the ECG record. An accurate 1.0 mV square wave can be superimposed on any of the lead positions at the input of the amplifier in order to standardize the amplifier gain. The appearance of the recorded square wave will tell the operator if the damping and frequency response are correct. A special time marker generator is also included which will put pulses with an accurate 1.0 second interval on the record to check the paper speed. The lead marker is a separate solenoid operated stylus which puts small square pulses on the side of the record in order to identify the position of the lead selector switch. Special contacts coupled with a relay and a delay circuit have been incorporated on the patient switch to enable the operator to switch from lead to lead without having to manually disable the amplifier.

Even though the Raytheon Electrocardiograph, Model EC-106, is a newcomer to the Medical Instrument field, its many users praise its superior styling and ease of operation.

HELIUM

IN THE PREHISTORY OF RAYTHEON

C. G. Smith
Research Division



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The group's first plan was to exploit a new type of heat engine based on a prior invention of Dr. Smith. The development was unsuccessful and other technical areas were considered. It was the age when radio broadcasting was new and exciting. Any improvement in equipment was eagerly snapped up by the buying public. A way around the need for expensive and short-lived batteries was almost certain of enthusiastic acceptance. Dr. Smith was well qualified for an attack on this problem. He had been a student of Dr. George W. Pierce in the Cruft Laboratory at Harvard during the period when Pierce himself was making important contributions to the amplifier and control tube field. Moreover, in his earlier work, Dr. Smith had developed gaseous amplifier and rectifier tubes based on the short path principle demonstrated by Hittorf some forty years before. The results of Dr. Smith's work were historic for the Company. The American Appliance Company, under the new name of Raytheon, developed and produced the gaseous rectifier known as the B tube and home radio became a practical, plug-in household appliance.

Dr. Smith has stuck to the pathways of science over the intervening years and is now a senior member of the Research Division where his talents and experience are focused on materials and phenomena at high temperatures.

Near the southern horizon shines the very hot Wolf-Rayet star Zeta Puppis emitting bright lines in the spectrum of ionized helium. Raytheon's prehistory begins with a consideration of the star and the meaning of its atomic spectrum. Niels Bohr in 1913 advanced the well-known Bohr Theory of the atom with the concept of outer electrons in quantized momentum and energy states, outside a dense nucleus. Studies of the atomic nucleus now consume billions of dollars per year in connection with A and H bombs. The outer electrons, however, not the nucleus, were the chief study in the teens and twenties. Raytheon began on July 1, 1922.

The Harvard astronomer, E. C. Pickering, long ago attributed an unknown series of lines in the spectrum of Zeta Puppis to light from the hydrogen atom, since the observed spectrum bore a simple mathematical relation to the Balmer series and other lines of hydrogen well known in the laboratory. Pickering assumed he was looking at hydrogen in some state not attainable in our earthly laboratories but which revealed itself brilliantly in the Wolf-Rayet star. The lines in question became known as the Pickering Series.

Producing these on earth became a pursuit of many researchers with no results whatever, so long as hydrogen alone was used in the laboratory sources. Bohr calculated some of the wave lengths to be expected from ionized helium. Ionized helium has one electron revolving around the nucleus, is suggestive of normal hydrogen and is as simple mathematically as hydrogen. The wave lengths of Bohr's calculation fell mostly in the far ultra violet and were unobservable in a stellar light source. However, one line $\lambda 4686$ in the violet blue was strong and should be visible. Also, the Pickering series was calculated to exist in moderate intensity.

The problem now shifted from hydrogen to helium. Could the spectrum of ionized helium be produced in the laboratory, and if so, could it be done without hydrogen in the tube? The very simple mathematical connection between the hydrogen lines and the helium lines in question would only complicate the issue in the days when Bohr's theory was new.

Professor T. Lyman of Harvard University suggested to a student, C. G. Smith, that he try to produce the spectrum of ionized helium in an electrodeless discharge in the purest attainable helium. Helium cost about $1,500 per cubic foot in those far away days, but Professor Lyman was able to secure a number of cubic feet for the laboratory.

The ring discharge in pure helium was produced. The Pickering series was strong, and λ4686 was brilliant and the ultraviolet lines were there quite accurately as predicted by Bohr. Meantime, Anderson in England made similar observations and Smith's work was never published.

However, during the spectral studies and the development of the ring discharge, knowledge of peculiar characteristics of helium was gained. Its long electronic free path among other things and its ease of purification were recognized. This knowledge was applied in the invention by Smith of the S tube, so named by Dr. Vannevar Bush at the American Radio and Research Corporation in 1920. (Dr. Bush was director of the laboratory.)

The S tube, the immediate ancestor of the BH tube, a thing of essential value to the success of Raytheon, came into being as a result of three properties of helium—the long electronic free path, ease of purification and the relative mildness of the sputtering qualities of helium ions.

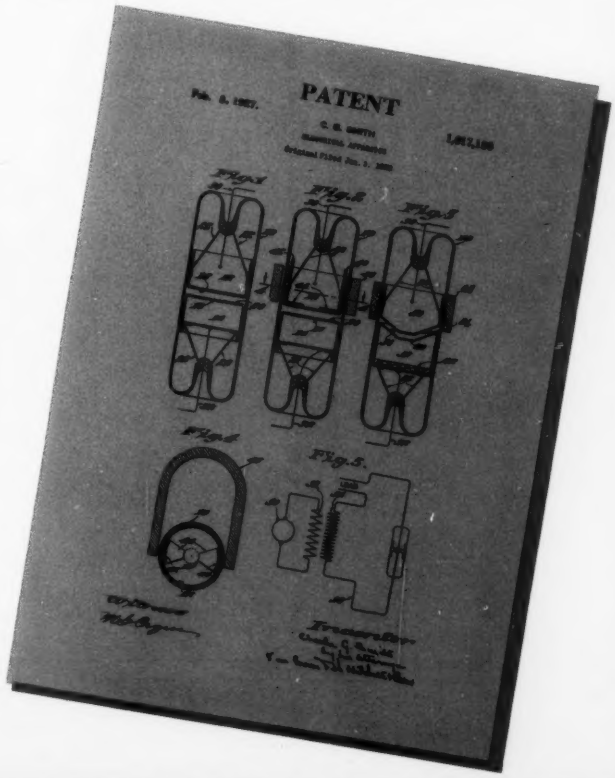
Gaseous tubes were plagued by disintegration (sputtering) of the electrodes and disappearance or occlusion of the gas. The amount of gas in the tube was limited because we employed the "Short Path" principle for insulation—the first application of this idea, although the basic physics of it had been known from Hittorf's work about forty years before. According to the principle, electrodes in a gas at a given pressure when closer than a certain minimum distance were effectively insulated from each other, although conduction between them was relatively easy when the space between was larger. We used a small free space in a critical region around a portion of the anode to act as an insulator. If a solid insulator had been used, sputtered metal would sooner or later have short circuited the device, making it inoperative.

In spite of the limitations on the amount of gas we could employ, we were able to use about five times as much helium as we could have used had other gases been employed. This obliging factor resulted from the unique long electronic free path in helium. The immense amount of helium usable was a big factor in combating the results of gaseous occlusion.

A hollow cathode was employed in the rectifier tubes. It had been observed during the spectral work at Harvard that the helium in the discharge tube disappeared even though no electrodes were in it. The glass of the tube seemed to soak up the gas. To avoid contact of the discharge region with the glass envelope of the S or the BH tubes, the hollow cathode was made a boundary and the discharge was wholly inside of it. Also, sputtered metal inside the hollow cathode was repeatedly banded about and could release occluded gas. Nevertheless, gas was quite appreciably occluded.

Dr. Bush suggested that the inside of the cathode be coated with the oxides of barium and strontium. This coating resulted in less electrical losses in the tube and reduced greatly the disappearance of the helium, yielding finally a tube of low loss and long life. Our patent claims covered the use of helium, the short path principle as incorporated, the hollow cathode with the coating inside. The tube operated as a useful rectifier in the form of the BH tube and was supplied for circuits used in the broadcast receiving sets in the middle twenties. The patents on the S tube were purchased from the American Radio and Research Corporation by Raytheon.

The endeavors were cast in the field of gaseous conduction because the vacuum electronics business of the time seemed to be monopolized by a very few large companies. The gaseous field was hard, but the properties of helium yielded a way out and around. Our company may be said to have had its first successful business as a result of unique properties of helium. Considering its curiously useful revelations in Zeta Puppis and its discovery in the sun before being found on earth, helium is truly a celestial gas. Its presence in some natural gas wells of Kansas and Texas reduced its price to a few cents a cubic foot instead of the $1,500 paid by Professor T. Lyman. Helium looms large in H bomb lore but for Raytheon its more benign associations constitute a pleasant memory.


PATENT

HELIUM

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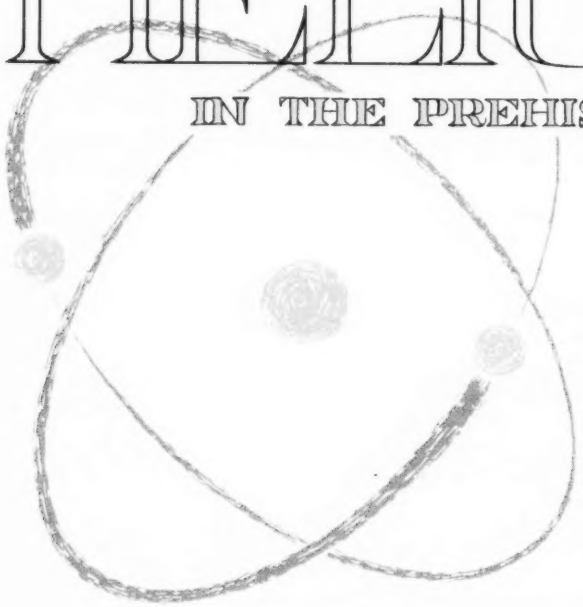

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Near the southern horizon shines the very hot Wolf-Rayet star Zeta Puppis emitting bright lines in the spectrum of ionized helium. Raytheon's prehistory begins with a consideration of the star and the meaning of its atomic spectrum. Niels Bohr in 1913 advanced the well-known Bohr Theory of the atom with the concept of outer electrons in quantized momentum and energy states, outside a dense nucleus. Studies of the atomic nucleus now consume billions of dollars per year in connection with A and H bombs. The outer electrons, however, not the nucleus, were the chief study in the teens and twenties. Raytheon began on July 1, 1922.

The Harvard astronomer, E. C. Pickering, long ago attributed an unknown series of lines in the spectrum of Zeta Puppis to light from the hydrogen atom, since the observed spectrum bore a simple mathematical relation to the Balmer series and other lines of hydrogen well known in the laboratory. Pickering assumed he was looking at hydrogen in some state not attainable in our earthly laboratories but which revealed itself brilliantly in the Wolf-Rayet star. The lines in question became known as the Pickering Series.

Producing these on earth became a pursuit of many researchers with no results whatever, so long as hydrogen alone was used in the laboratory sources. Bohr calculated some of the wave lengths to be expected from ionized helium. Ionized helium has one electron revolving around the nucleus, is suggestive of normal hydrogen and is as simple mathematically as hydrogen. The wave lengths of Bohr's calculation fell mostly in the far ultra violet and were unobservable in a stellar light source. However, one line $\lambda 4686$ in the violet blue was strong and should be visible. Also, the Pickering series was calculated to exist in moderate intensity.

The problem now shifted from hydrogen to helium. Could the spectrum of ionized helium be produced in the laboratory, and if so, could it be done without hydrogen in the tube? The very simple mathematical connection between the hydrogen lines and the helium lines in question would only complicate the issue in the days when Bohr's theory was new.

Professor T. Lyman of Harvard University suggested to a student, C. G. Smith, that he try to produce the spectrum of ionized helium in an electrodeless discharge in the purest attainable helium. Helium cost about $1,500 per cubic foot in those far away days, but Professor Lyman was able to secure a number of cubic feet for the laboratory.

The ring discharge in pure helium was produced. The Pickering series was strong, and λ4686 was brilliant and the ultraviolet lines were there quite accurately as predicted by Bohr. Meantime, Anderson in England made similar observations and Smith's work was never published.

However, during the spectral studies and the development of the ring discharge, knowledge of peculiar characteristics of helium was gained. Its long electronic free path among other things and its ease of purification were recognized. This knowledge was applied in the invention by Smith of the S tube, so named by Dr. Vannevar Bush at the American Radio and Research Corporation in 1920. (Dr. Bush was director of the laboratory.)

The S tube, the immediate ancestor of the BH tube, a thing of essential value to the success of Raytheon, came into being as a result of three properties of helium—the long electronic free path, ease of purification and the relative mildness of the sputtering qualities of helium ions.

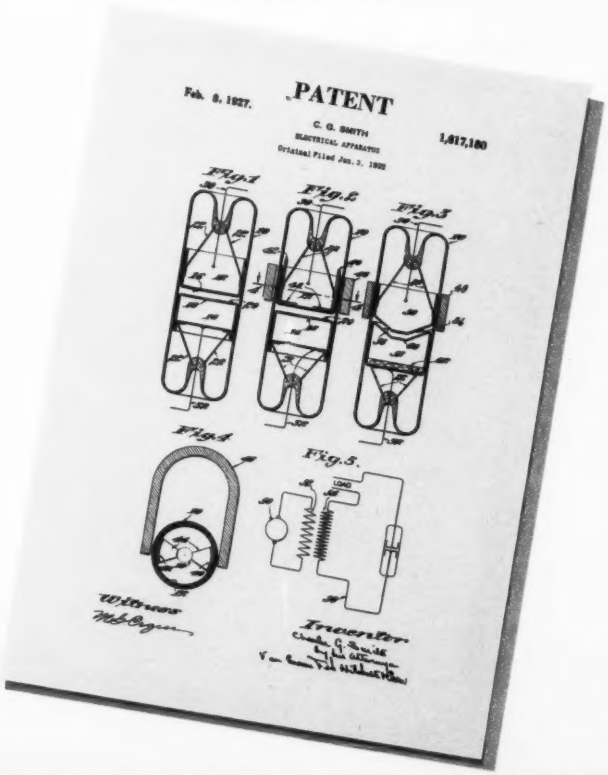
Gaseous tubes were plagued by disintegration (sputtering) of the electrodes and disappearance or occlusion of the gas. The amount of gas in the tube was limited because we employed the "Short Path" principle for insulation—the first application of this idea, although the basic physics of it had been known from Hittorf's work about forty years before. According to the principle, electrodes in a gas at a given pressure when closer than a certain minimum distance were effectively insulated from each other, although conduction between them was relatively easy when the space between was larger. We used a small free space in a critical region around a portion of the anode to act as an insulator. If a solid insulator had been used, sputtered metal would sooner or later have short circuited the device, making it inoperative.

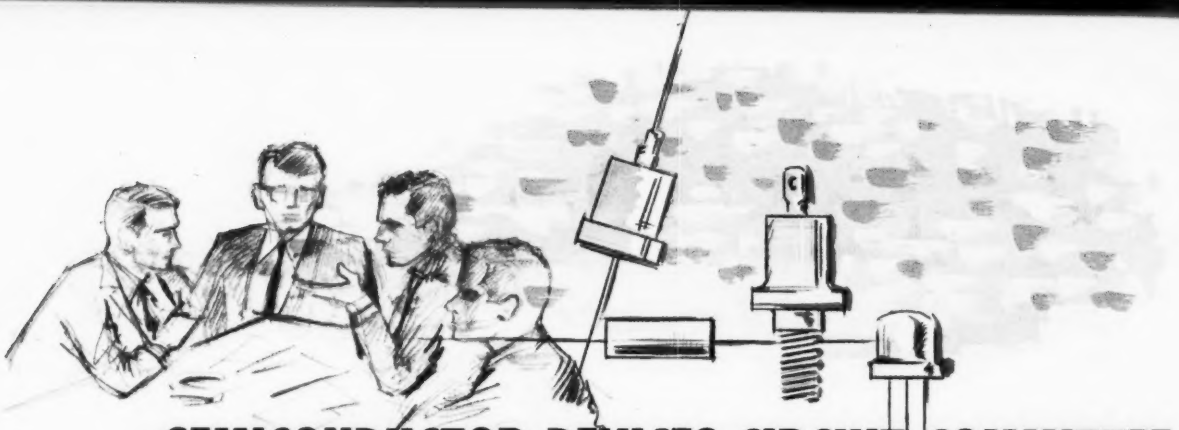
In spite of the limitations on the amount of gas we could employ, we were able to use about five times as much helium as we could have used had other gases been employed. This obliging factor resulted from the unique long electronic free path in helium. The immense amount of helium usable was a big factor in combating the results of gaseous occlusion.

A hollow cathode was employed in the rectifier tubes. It had been observed during the spectral work at Harvard that the helium in the discharge tube disappeared even though no electrodes were in it. The glass of the tube seemed to soak up the gas. To avoid contact of the discharge region with the glass envelope of the S or the BH tubes, the hollow cathode was made a boundary and the discharge was wholly inside of it. Also, sputtered metal inside the hollow cathode was repeatedly banded about and could release occluded gas. Nevertheless, gas was quite appreciably occluded.

Dr. Bush suggested that the inside of the cathode be coated with the oxides of barium and strontium. This coating resulted in less electrical losses in the tube and reduced greatly the disappearance of the helium, yielding finally a tube of low loss and long life. Our patent claims covered the use of helium, the short path principle as incorporated, the hollow cathode with the coating inside. The tube operated as a useful rectifier in the form of the BH tube and was supplied for circuits used in the broadcast receiving sets in the middle twenties. The patents on the S tube were purchased from the American Radio and Research Corporation by Raytheon.

The endeavors were cast in the field of gaseous conduction because the vacuum electronics business of the time seemed to be monopolized by a very few large companies. The gaseous field was hard, but the properties of helium yielded a way out and around. Our company may be said to have had its first successful business as a result of unique properties of helium. Considering its curiously useful revelations in Zeta Puppis and its discovery in the sun before being found on earth, helium is truly a celestial gas. Its presence in some natural gas wells of Kansas and Texas reduced its price to a few cents a cubic foot instead of the $1,500 paid by Professor T. Lyman. Helium looms large in H bomb lore but for Raytheon its more benign associations constitute a pleasant memory.





SEMICONDUCTOR DEVICES CIRCUIT COMMITTEE

J. Mofenson
Wayland Laboratory

As a major manufacturer of semiconductor devices and electronic equipment, Raytheon has a vital interest in communicating transistor and diode information to its engineers. The establishment of the Semiconductor Devices Circuit Committee accomplishes this purpose. This committee, which is concerned primarily with equipment applications, operates as a clearinghouse for ideas on present and projected uses of transistors and other semiconductor devices. Its membership includes design and engineering representatives from the Equipment, Research, Semiconductor, and Power Tube Divisions.

The committee is an outgrowth of the old Transistor Steering Committee formed in January 1953, when the transistor first made its impact on equipment design. It was reactivated in 1957 to include all semiconductor devices, and regular meetings have been held at about six-week intervals, alternating between the Wayland Laboratory and Waltham.

Because literature on transistor technology appearing in technical magazines has been sketchy and stale, the design engineer has frequently been limited in selecting and using transistors. To compensate for this roadblock, the committee has proved effective as a medium for exchanging knowledge and stimulating creative thought. The committee does this by distributing memoranda on transistor applications to its members and by including these memoranda in the minutes of meetings. Also, by encouraging first-name friendships between members, the committee tends to break down normal organizational barriers.

Technical sessions of the committee encompass Raytheon's entire effort in the field of equipment development using semiconductors. Members discuss topics of special interest and current problems for possible solutions. New circuit developments, testing techniques, and laboratory instrumentation are typical items discussed.

One of the major problems facing the committee is the military use of transistors. To what extent should they replace vacuum tubes in military equipment without sacrificing reliability? How fast should the changeover be made? In what kinds of military gear are transistors more suitable than tubes? These are the types of questions that the committee is coping with and is aiming to answer.

The committee maintains close contact with equipment designers throughout Raytheon and with various Electronic Industries Association (formerly RETMA) groups and Military Specifications writers concerned with semiconductor applications.

Publications & Papers

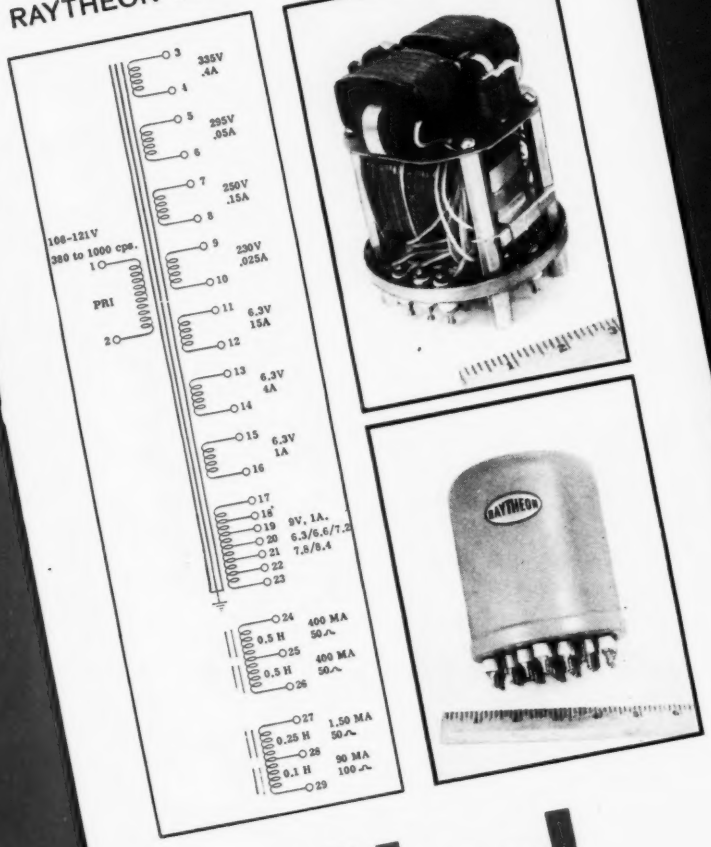
These papers have been approved by Raytheon's Technical Publications Panel:

R. A. Axford	"Heat Conduction in Internally Cooled Nuclear Reactors"
A. Bergson	"Silicon Diode Application Notes, Part II"
C. F. Coit and T. F. Mahoney	"An Airborne Program Computer"
D. A. Copson	"Microwave Freeze-Drying Process"
D. K. Das	"A Differential Expansion Diffusion Couple Welder"
G. J. Foundas and G. H. Allen	"Collection, Analysis and Application of Component Reliability Data"
G. J. Foundas and G. H. Allen	"Controlled Testing of Copper-Clad Laminates"
J. Gaziano	"Driver Tubes for Hybrid Auto Radio Receivers"
W. Harvey	"Raytheon Regulated Electronic Speed Drive"
L. H. Holway, Jr.	"Choice of Basis Functions for Multigroup Perturbation Calculations"
T. F. Hueter	"Instrumentation for Medical Ultrasonics"
C. L. Larson	"Heat Transfer in a Cross Flow Nuclear Reactor"
W. H. Ryer and W. E. Sheehan	"Present Status of Transistor Rectifier Design Procedures"
D. Schiff	"Second Order Perturbation Theory"
E. Schloemann and J. R. Zender	"Ferromagnetic Resonance in Polycrystalline Nickel Ferrite Aluminate"
E. Schloemann	"New Type of Ferromagnetic Microwave Amplifier"
C. A. Underwood	"Involute Gear Elements Simplified by Using the Williamson Tables"
R. D. Wilson	"The Effect of Manufacturing Tolerances on Vacuum Tube Shock and Vibration Output"
S. Ziering and D. Schiff	"Boundary Value Problems in Transport Theory"

A famous Raytheon first . . . the BH tube. This gas rectifier was Raytheon's first successful product. Freeing the home radio from batteries, it launched the Company in the electronics business.

This ad is part of a current multiple-page series featuring a variety of Raytheon magnetic and electro-mechanical components. Each component is described in terms of a particular advantage ("Size", "Shape", "Color", etc.) which it offers to the designer of electronic equipment. This segment points out an extremely important result of Raytheon's new fluorochemical design techniques — drastic reduction in size.

RAYTHEON MAGNETIC COMPONENTS



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